Optical MEMS Used to Detect Micro-corrosion in Steel Cans of Food and Beverage Industries

Optical MEMS Used to Detect Micro-corrosion

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Abstract

The use of micro components in the food and beverage industry has contributed to the development of new technologies, as the manufacturing of micro optical sensors (MOS). These micro devices are controlled by micro-electromechanical systems, and applied to detect micro-organisms (MOs) formed inside of the steel canswhich are not visible for the naked eye. These MOs are formed for the microbiological corrosion, in the storage and manufacturing process, by the presence of air pollutants as sulfurs in Mexicali considered as arid region and Tijuana as industrial city and uncontrolled climate factors in indoor of industrial plants. In the process of manufacturing and packaging of food and beverages, MOs are not observed, and it is necessary to be detected using micro-opto-electromechanical systems (MOEMS) to avoid that deteriorated food and beverages. These polluted products are consumed by people in this region and others cities of Mexico and of the United States, where are commercialized and cause serious health problems. For this reason, the analysis of microbiological corrosion (MBC) was made to detect and determine the principal chemical agents, as air pollutants originate this corrosion process. Also the climatic parameters were evaluated as factors which are combined with the pollutants agents to generate the MBC. The research was made in the cities mentioned above in the period of 2010 to 2011. The MBC was analyzed by the Scanning Electron Microscopy (SEM) and the Mat Lab Simulation to determine in a future the behavior of this process that occurs in the steel cans where conserve food and beverages are concern principally to owners of the industrial plants of this type of companies.

Keywords

MOEMS; Atmospheric Corrosion; Climatic Factors; SEM Analysis

Introduction

MSO coupled with the micro-electromechanical systems (MEMS), and micro and macro actuators are used to detect the steel cans (SC) with MO and are separated to avoid the deterioration of food and beverages and healthy problems [Lopez et al. (2012)]. MOEMSs are very efficient to operate and support and further to maintain the SC in good conditions to be used as reliable product [Gustavo et al. (2011)]. The existence of MBC occurs by drastic variations of climatic factors such as humidity and temperature combined with the presence of chemical agents as sulfurs in Mexicali and chlorides in Tijuana. This air pollution exceeds the air quality standards described by the Secretaria de Medio Ambiente y (this is part of the real name in Mexico) Recursos Naturales (SEMARNAT of Mexico) and the Environmental Protection Agency (EPA of USA) in some periods of the year. The air pollutants mentioned above, penetrate to indoor industrial plants in each city evaluated affecting the indoor environment of industrial plants [AHRAE (1999)] and deteriorating the food and beverages. This study presented figures as micro scale of the presence of microorganisms which are generated by the MBC, showing the colonies of MO in each city evaluated by SEM. The analysis presented different corrosivity levels (CL) in indoor of industrial plants.

Optical Sensors

In the electronics industry, the optical sensors are used with a high frequency, with certain light-sensitive components, as sense systems that can change their behavior depending of the capacity of with the electrical light [Osiander et al. (2002)]. These sensors are used frequently in the industrial plants of food and

beverage companies to detect micro and macro strange components of the products packaged and consumed by residents in some regions of the northwest of Mexico. The light-sensitive components commonly used are: photo resist which reduces the resistance when light is not received. The photodiode leads in reverse under light. The phototransistor emitter-collector have a principal characteristic that is the detection of objects withou ligth. The response of the photo resist is much slower than that of a photodiode or phototransistor, and it responds more slowly to changes in light. Depending on the specific application may require additional electronic and optical components: lenses, filters, signal amplifier, etc. At the industry a lot electronic devices are used frequently, as optical sensors including electronic circuit, filters and other electronic components [Allen et al. (1998)].

MOEMS Operations

MOEMs are important microelectronic devices used in the food and beverage industries. Its micro sensors are coupled with other micro components and use a laser ray very sensible to detect the microorganisms in the SC [Avella et al. (2005)]. This type of micro devices operates at high frequency in the order of megahertz, to send the detected signawhen the SC operates with a good condition to detect the MO . MOEMSs are very small and can be installed in any place of the industrial machines which are used in the manufacturing process of checking of SC and filing process in food and beverage cans, principally [Osiander et al. (2002)]. These micro devices manipulate the optical signals according to the necessity of the industrial processes, including a variety of this type of micro components, varying in some parameters such as frequency, micro size, quantity and type of operations with switches, optical cross-connect, stable or variable and others. Its micro optical components are manufactured with micro technology adapted to micro-optics and standard micromachining of specialized materials as silicon, silicon dioxide, silicon nitride and gallium arsenide. Fabricating the MOEMS is necessary by means of two methods, being the first step the manufacturing of MEMS and also the adaptation of the optical sensors, to complete the micro devices with the functions required [Allen et al. (1998)]. Both technologies involve the processing similar to integrated circuits, and micromachining similar to fabrication of micro sensors, only do the micromechanics systems are adapted with the optical sensor in the adequate place. MOEMS offers a wide variety of miniaturization and applications in sensors and actuators, robotics, accelerometers, micro valves, flow controllers, global positioning systems (GPS) component miniaturization; and a host of other sensors and actuators for applications to space, air, land, and sea vehicles, as well as industrial, biotechnology, and consumer electronics.

FIG. 1 OPTICAL SENSORS IN MEMS: (a) USED IN THE FOOD AND BEVERAGE INDUSTRIES AND (b) MOEMS DAMAGED BY MICROBIOLOGICAL CORROSION

Stages of Manufacturing Processes in Food and Beverage Industries

The manufacturing steps in food and beverage industries are shown in Figure 2 [CIAA (2004, 2005)].

a) Washing. Recipients are cleaned to remove bacteria that could alter the nutritional value of food and beverage.

b) Scalding. The product is subjected to immersion in hot water to remove the enzymes that produce food and beverage and darkness of the microorganisms that cause rancidity.

c) Preparation. Before placing food and beverage in the recipients, final products are inspected very strictly their quality I at laboratory to begin the manufacturing process.

d) Regulation. The food and beverage are placed in the recipients, to add the necessary preservatives to conserve it.

e) Air extraction process. The recipient passes through a steam tunnel at 40°C to avoid the unpleasant taste and odor.

f) Sterilization. It is very important for the complete removal of microorganisms that may remain in the previous stages.

g) Cooling. Once the recipients are sterilized, a cooled under running cold water or cold water immersion occurs.

h) Labeling. The label can be placed with the adequate legends of the products ingredients, expiration dates and lot numbers.

i) Packaging. In this section, the final products are organized in boxes to be sending to the customers.

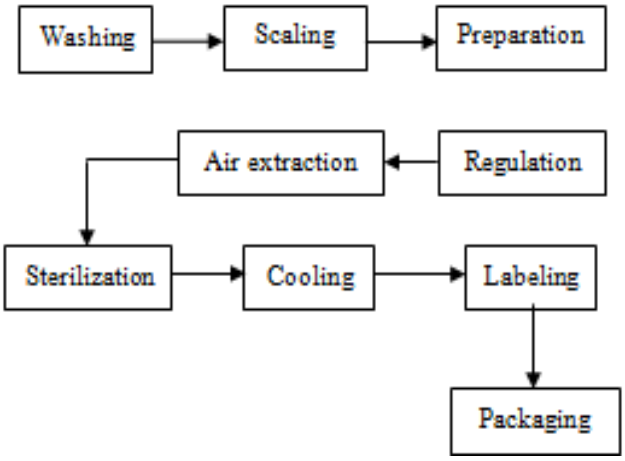

FIG. 2 STEPS OF THE MANUFACTURING PROCESS OF THE FOOD AND BEVERAGES INDUSTRIES

Experiment

Steps of the study

This study was made with a type of MOEMS to determine their operation yielding and detect at high velocity the MO and avoid the generation and propagation of MO inside of the SC being a factor of deterioration of food and beverages. The main characteristics of this MOEMS used were a frequency of 5MegaHertz-MH, a voltage of 10microvolts-μV and a response time of 0.2microseconds-μs. The principal parameters that generate the MBC are mentioned next:

Climate factors. The climate is composed of several parameters, where the RH and temperature are the most important damage of micro sensors. Scientists who have analyzed the AC, considered that the climatic parameters are the principal factor of damage of the connections and connectors of MOEMS. Drastic changes in humidity and temperature at certain times of year, have caused deterioration of electrical components due to the CL.

Microscopy technique. The morphology of the corrosion products of SC was examined with the SEM technique, to determine the air pollutants which reacted with the inside of the metal surfaces of SC.

Numerical analysis. Mathematical correlation was performed with Mat Lab software to determine the CL indoor industrial plants evaluated in the cities mentioned above, in spring, summer, autumn and winter. This simulation analysis obtained the degree of deterioration (GD) of copper surfaces, with the correlation of climatic factors (temperature and humidity) and air pollutants (SO_x and NO_x) to determine the corrosion rate (CR).

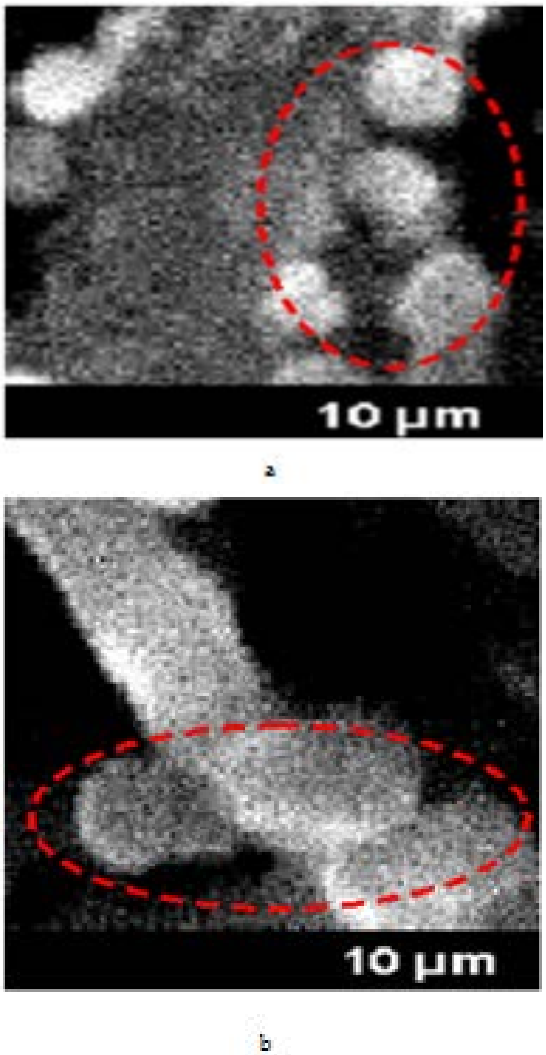

FIG. 3 ANALYSIS OF THE FORMATION AND PROPAGATION OF COLONIES OF MICROORGANISM IN: (A) MEXICALI AND (B) TIJUANA (2011).

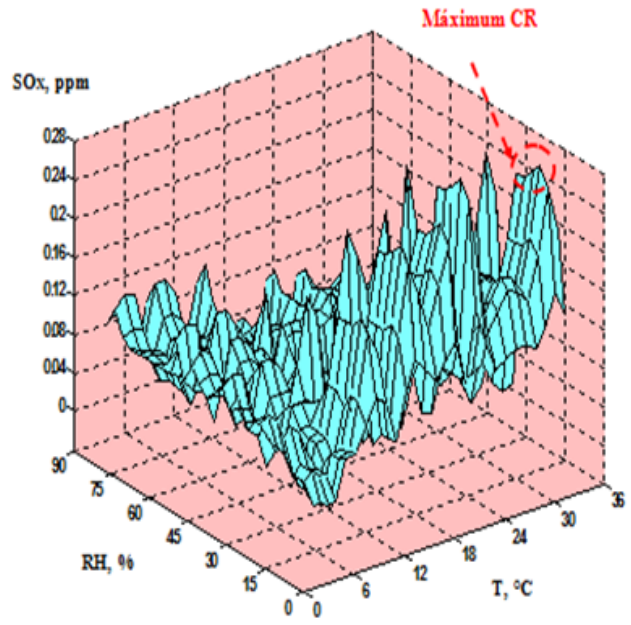

FIG. 4 CORRELATION ANALYSIS OF CR WITH CLIMATIC FACTORS AND AIR POLLUTANTS IN MEXICALI IN WINTER (2011)

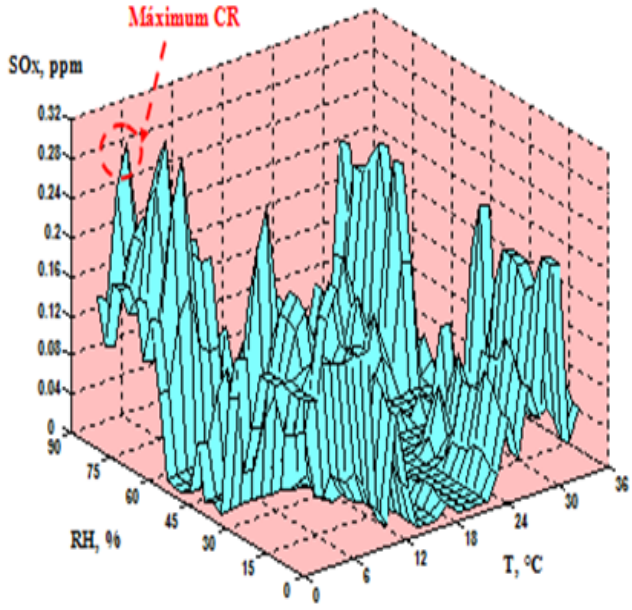

FIG. 5 CORRELATION ANALYSIS OF CR WITH CLIMATIC FACTORS AND AIR POLLUTANTS IN TIJUANA IN WINTER (2011)

MatLab Simulation

With the analysis of the MO with SEM, the fast development of the microorganisms can be observed and the type of MOs were evaluated with their physicochemical and biological properties to determine the similar characteristics of the MO formed by the microbiological process. After this evaluation, a mathematical simulation [Walsh et al. (2010)] was made with respect to the behavior of the MBC influenced by the RH and temperature variations and the concentration level of sulfurs in both cities evaluated. In figure 4 which represents the Mexicali city, the maximum level of CR was at 28% of RH and 35°C levels in a day at the beginning of February in 2011 and in Tijuana was the major intensity of CR at 88% of RH and 7°C, evaluated in November 28th of the year period evaluated. in a day of final of November of 2011. This indicated that when the condensation activity being more probability of the generation and propagation of this phenomenon occurs, which affects the properties of the materials of SC and tends to degrade the food and beverages packed in these type of industrial plants.

Conclusions

Micro optical sensors with MEMS used in the food and beverages industries detected the presence of MO in the SC used to conserve food and beverages packed in the cities mentioned above. The development of MO in this type of industries has damaged the metallic cans and caused economic losses which are maintained concerning owners, managers and specialized people in these industrial plants. The mathematical simulation indicated that the major CR occurr in the winter different months in each city. In Tijuana, the CR occured was the higher level compared with Mexicali. One interesting aspect was the determination of at values higher than 75% and 35ºC levels of humidity and temperature levels began the development of the MO. In addition with the presence of sulfur oxides, the air pollutant with the most negative effect in the SC, with concentration levels that exceeded the air quality standards, the propagation of MO was higher. The nitrogen oxides in Mexicali and chlorides in Tijuana were other air pollutants having an adverse effect onn the degradation of SC. The use of coatings in the metallic surface of SC was an important factor to avoid the microbiological corrosion, but it was presented in minor damage.

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